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(30)Priority

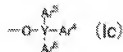
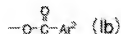
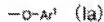
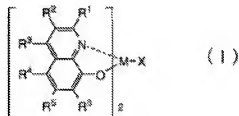
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(54) ORGANIC ELECTROLUMINESCENT ELEMENT

(57)Abstract:

PROBLEM TO BE SOLVED: To improve a luminescence efficiency of an organic electroluminescent element utilizing phosphorescence luminescence and to secure a driving stability of the same.

SOLUTION: In an organic electroluminescent element having an anode, a luminous layer, and cathode laminated on a substrate in order, the luminous layer contains a compound having N-phenylcarbazole skeleton as a principal component and an organic metal complex including at least one kind of metal selected from group 7 or 11 of the periodic table as a sub component and a blocking layer containing a compound expressed in the following general formula (I) is included



between the luminous layer and the cathode. (R1, R2, R3, R4, R5 and R6 are each hydrogen atom or optional substituent and M represents a metal atom selected from aluminum, gallium and indium. X is expressed as one of formulae (1a), (1b), (1c) shown below). (Ar1, Ar2, Ar3,

Ar4 and Ar5 are each an aromatic hydrocarbon group containing a substituent or an aromatic heterocyclic group containing a substituent, and Y represents silicon or germanium).

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Notes:

1. Untranslatable words are replaced with asterisks. (****).
2. Texts in the figures are not translated and shown as it is.

Translated: 23:44:10 JST 06/04/2010

Dictionary Last updated 03/12/2010 / Priority: 1. Chemistry / 2. Electronic engineering / 3. Mathematics/Physics

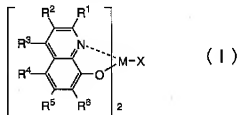
CLAIM + DETAILED DESCRIPTION

[Claim(s)]

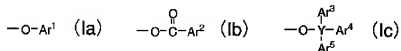
[Claim 1] Organic electroluminescence devices which come to laminate an anode, a luminous layer, and a cathode on a substrate one by one, comprising:

A compound in which a luminous layer has N-phenyl carbazole skeleton.

At least one metal chosen from periodic table 7 thru/or 11 groups.

[Chemical formula 1]

(R¹ - R⁶ express a hydrogen atom or arbitrary substituents among a formula, and M expresses the metal atom chosen from an aluminium, gallium, and indium.) General formula (I) Naka and X are denoted by the general formula (Ia) shown below or (Ib) or, and (Ic).

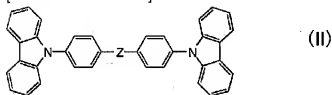
[Chemical formula 2]

(Among a formula, Ar¹ - Ar⁵ express the aromatic heterocycle group which may have the aromatic-hydrocarbon-rings group or substituent which may have a substituent, and Y expresses silicon or germanium.)

[Claim 2] $R^1 - R^6$ in general formula (I) A hydrogen atom, a halogen atom, An alkyl group, an aralkyl group, an alkenyl group, an allyl group, a cyano group, an amino group, The organic electroluminescence devices according to claim 1 which are the aromatic heterocycle groups which may have an aromatic-hydrocarbon-rings group or a substituent which may have an acyl group, an alkoxycarbonyl group, a carboxyl group, an alkoxy group, an alkylamino group, a HAROARUKIRU group, a hydroxyl group, and a substituent.

[Claim 3] The organic electroluminescence devices according to claim 1 or 2, wherein a compound which has N-phenyl carbazole skeleton is a compound denoted by following general formula (II).

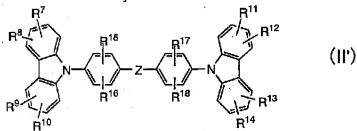
[Chemical formula 3]



(Z shows a divalent connecting group among a formula.) A carbazolyl group and a phenylene group may have arbitrary substituents respectively.

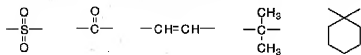
[Claim 4] The organic electroluminescence devices according to claim 3, wherein a compound which has N-phenyl carbazole skeleton which is general formula (II) and is expressed is denoted by a following general formula (II').

[Chemical formula 4]



the inside of a formula, $R^7 - R^{18}$ -- each -- independent -- a hydrogen atom and a halogen atom. An alkyl group, an aralkyl group, an alkenyl group, a cyano group, an amino group, an acyl group, An alkoxycarbonyl group, a carboxyl group, an alkoxy group, an alkylamino group, An aralkyl amino group, a HAROARUKIRU group, a hydroxyl group, an aryloxy group, An aromatic-hydrocarbon-rings group or an aromatic heterocycle group which may have a substituent is expressed, R^7 , R^8 and R^9 , R^{10} and R^{11} , R^{12} and R^{13} , R^{14} and R^{15} , R^{16} and R^{17} , and R^{18} may form a ring by adjoining substituents, respectively. A connecting group which Z shows a divalent connecting group and is shown in direct coupling, an oxygen atom, a

sulfur atom, and the following, [Chemical formula 5]



It is expressed with either of the aromatic-hydrocarbon-rings groups or aromatic heterocycle groups which may have a substituent.

[Claim 5]The organic electroluminescence devices according to any one of claims 1 to 4, wherein periodic table 7 thru/or 11 groups' metal is chosen from ruthenium, rhodium, palladium, silver, rhenium, osmium, iridium, platinum, and gold.

[Claim 6]The organic electroluminescence devices according to any one of claims 1 to 5 having a positive hole transportation layer between a luminous layer and an anode.

[Claim 7]The organic electroluminescence devices according to any one of claims 1 to 6 having an electron transport layer between a hole blocking layer and a cathode.

[Claim 8]The organic electroluminescence devices according to any one of claims 1 to 7, wherein thickness of a hole blocking layer is in the range of 0.5-50 nm.

[Detailed Description of the Invention]

[0001]

[Field of the Invention]This invention relates to organic electroluminescence devices, and relates to the thin film type device which emits light applying an electric field to the luminous layer which comprises an organic compound in detail.

[0002]

[Description of the Prior Art]Although what doped Mn which is a luminescence center, and rare earth elements (Eu, Ce, Tb, Sm, etc.) is common to ZnS and CaS which are the II-VI group compound semiconductors of an inorganic material, SrS, etc. as a thin film type electroluminescence (EL) element conventionally, The EL element produced from the above-mentioned inorganic material has the problem that one alternating current drive is [necessity (50-1000 Hz) and 2 drive voltage] high (~200V) and that the formation of 3 full color has the high cost of difficulty (especially blue) and 4 circumference drive circuit.

[0003]However, development of the EL element using an organic thin film came to be performed in recent years for improvement of the above-mentioned problem. In order to raise luminous efficiency especially, the kind of electrode is optimized for the purpose of the efficiency raising of Carrier pouring from an electrode, With development (Appl. Phys. Lett., 51 volumes, 913 pages, 1987) of the organic electroluminescence devices which provided the positive hole transportation layer which comprises aromatic diamine, and the luminous layer

which comprises the aluminium complex of 8-hydroxyquinoline, An extensive improvement of luminous efficiency is made as compared with the EL element using single crystals, such as conventional anthracene, and practical use characteristics are approached.

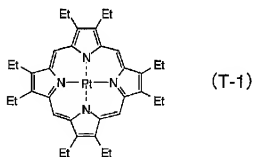
[0004] Besides the electroluminescence devices using the above low-molecular materials, [as a material of a luminous layer] Poly (p-phenylenevinylene), poly [2-methoxy-5-(2-ethylhexyloxy)-1,4-phenylenevinylene], Development of the electroluminescence devices using polymeric materials, such as poly (3-alkyl thiophene), and development of the element which mixed a low-molecular luminescent material and electron transfer material to polymers, such as polyvinyl carbazole, are also performed.

[0005] By the way, using not fluorescence but phosphorescence is also examined as a trial which mentions the luminous efficiency of an element. If phosphorescence is used, namely, luminescence from a triplet excited state is used, about 3-time efficiency raising is expected compared with the element using the conventional fluorescence (singlet). Although making a coumarin derivative and a benzophenone derivative into a luminous layer for this purpose was examined (the 51st Japan Society of Applied Physics union lecture meeting, 28 a-PB-1990 [7 or]), only very low luminance was obtained. Then, although using a europium complex had been examined as a trial using a triplet state, this did not result in efficient luminescence, either.

[0006] It was reported by using these days the platinum complex (T-1) shown below that efficient red light is possible (Nature, 395 volumes, 151 pages, 1998). Then, efficiency is further improved greatly by green emission with doping the iridium complex (T-2) shown below to a luminous layer (Appl. Phys. Lett., 75 volumes, 4 pages, 1999).

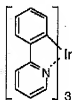
[0007]

[Chemical formula 6]



[0008]

[Chemical formula 7]



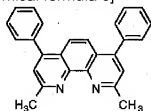
(T-2)

[0009]

[Problem to be solved by the invention] In order to apply organic electroluminescence devices to indicating elements, such as a flat panel display, while improving the luminous efficiency of an element, it is necessary to fully secure the stability at the time of a drive. However, the present condition is that the driving stability of the efficient organic electroluminescence devices using a phosphorescence molecule (T-2) given in above-mentioned document is insufficient for practical use (Jpn. J. Appl. Phys., 38 L 1502 pages, 1999).

[0010] It is presumed that the proximate cause of the above-mentioned drive deterioration is based, for example on deterioration of the thin film shape of the hole blocking layer in the element structure of a substrate / anode / positive hole transportation layer / luminous layer / hole blocking layer / electron transport layer / cathode **. It is thought that deterioration of this thin film shape originates in crystallization (or condensation) of the organic amorphous thin film by generation of heat at the time of an element drive, etc., etc. It is thought that this heat-resistant lowness originates in the lowness of the glass transition temperature (it omits the following T_g) of material. The phenanthroline compound shown below as a hole blocking layer in above-mentioned document (thing about the element using (T-2) as a phosphorescence molecule) [0011]

[Chemical formula 8]



[0012] Although it is used, since this compound has small molecular weight, it crystallizes and condenses easily and thin film shape deteriorates. The role of a hole blocking layer is preventing the positive hole poured in from the anode leaking to an electron transport layer, and limiting a positive hole and an electronic recombination area in a luminous layer. Although efficient-ization of a luminous layer is attained by this, if the homogeneity of the thin film of a hole blocking layer is lost by crystallization and condensation, the above-mentioned positive hole stopping power power will decline, and the fall of luminous efficiency and luminescent

brightness will be caused as a result.

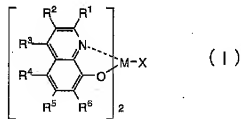
[0013]The actual condition is that the organic electroluminescence devices using a phosphorescence molecule are holding the big problem in the driving stability of an element towards utilization from the above-mentioned Reason. It is not desirable not to improve the driving stability of organic electroluminescence devices, when considering application of indicating elements, such as a flat panel display, Lighting Sub-Division, etc. As a result of inquiring wholeheartedly for the purpose of providing the organic electroluminescence devices which have efficient and high driving stability in view of the above-mentioned actual condition, this invention person finds out that an aforementioned problem is solvable by using a specific organometallic complex compound for a hole blocking layer, and came to complete this invention.

[0014]

[Means for solving problem]Namely, in the organic electroluminescence devices which, as for the gist of this invention, come to laminate an anode, a luminous layer, and a cathode on a substrate one by one, The luminous layer contains the compound which has N-phenyl carbazole skeleton, and the organometallic complex containing at least one metal chosen from periodic table 7 thru/ or 11 groups, And it consists in the organic electroluminescence devices having a hole blocking layer containing the compound denoted by following general formula (I) between a luminous layer and a cathode.

[0015]

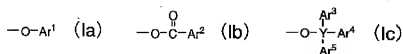
[Chemical formula 9]



[0016](R¹ - R⁶ express a hydrogen atom or arbitrary substituents among a formula, and M expresses the metal atom chosen from an aluminium, gallium, and indium.) General formula (I) Naka and X are denoted by the general formula (Ia) shown below or (Ib) or, and (Ic).

[0017]

[Chemical formula 10]



[0019]

The compound which has N-phenyl carbazole skeleton.

The "hole blocking layer" in this invention puts the layer provided in contact with the interface by the side of the cathode of a luminous layer.

[0020] Although $R^1 - R^6$ express a hydrogen atom or arbitrary substituents, [in said general formula (I)] desirable -- hydrogen atom; -- the alkenyl-group; cyano group; amino group; acyl group; methoxy group of the carbon numbers 2-6, such as aralkyl group; vinyl groups, such as alkyl-group; benzyl of the carbon numbers 1-6, such as halogen atom; methyl groups, such as chlorine and bromine, and an ethyl group,. The alkoxy group of the carbon numbers 1-6, such as an ethoxy group; A methoxycarbonyl group, alkoxy carbonyl group [of the carbon numbers 1-6 of an ethoxycarbonyl group etc.]; -- carboxyl group; -- a phenoxy group. Aryloxy groups, such as a benzyloxy group; Dialkylamino group; dibenzylamino groups, such as a diethylamino group and a diisopropylamino group, diaralkylamino group [, such as a diphenethyl amino group,]; -- alpha-HAROARUKIRU group [, such as a trifluoromethyl group,]; -- hydroxyl group; -- aromatic heterocycle groups which may have aromatic-hydrocarbon-rings group; substituents, such as a phenyl group, a naphthyl group, etc. which may have a substituent, such as a thienyl group and a pyridyl group, are expressed.

[0021][as a substituent which said aromatic hydrocarbon rings and an aromatic heterocycle can take] Halogen atoms, such as a fluorine atom; Alkenyl-group; methoxycarbonyl groups, such as an alkyl-group; vinyl group of the carbon numbers 1-6, such as a methyl group and an ethyl group, The alkoxycarbonyl group of the carbon numbers 1-6 of an ethoxycarbonyl group etc.; A methoxy group, The alkoxy group of the carbon numbers 1-6, such as an ethoxy group; HAROARUKIRU groups, such as acyl groups, such as dialkylamino groups, such as aryloxy group; dimethylamino groups, such as a phenoxy group and a benzyloxy group, and a diethylamino group, and an acetyl group, and a trifluoromethyl group, a cyano group, etc. are mentioned.

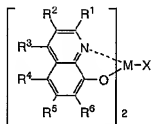
[0022] A hydrogen atom, an alkyl group, a halogen atom, or a cyano group is mentioned more preferably as R¹ thru/or R⁶. Especially as R⁴, a cyano group is preferred. M shows Al atoms, a

Ga atom, or In atom. X is denoted by either said general formula (Ia), (Ib) or (Ic), and Y expresses the atom of either Si or germanium among each formula, and, [Ar¹ - Ar⁵] Aromatic heterocycle groups which may have a substituent, such as aromatic-hydrocarbon-rings groups, such as a phenyl group, a biphenyl group, and a naphthyl group, or a thienyl group, and a pyridyl group, are expressed.

[0023] Although the desirable example of a compound denoted by said general formula (I) is shown in the following Table 1 - 2, it does not limit to these.

[0024]

[Table 1]



番号	M	R ¹ ~R ³	R ⁴ ~R ⁶	X
(1)	Al	R ¹ : -CH ₃	—	
(2)	Al	R ¹ : -CH ₃	—	
(3)	Al	R ¹ : -CH ₃ R ³ : -CH ₃	—	
(4)	Al	R ¹ : -CH ₃	R ⁴ : -CN	
(5)	Al	R ¹ : -CH ₃ R ³ : -CH ₃	R ⁴ : -CN	
(6)	Ga	R ¹ : -CH ₃	R ⁴ : -CN	
(7)	Al	R ¹ : -CH ₃	—	
(8)	Ga	R ¹ : -CH ₃	—	
(9)	Al	R ¹ : -CH ₃ R ³ : -CH ₃	—	
(10)	Al	R ¹ : -CH ₃ R ³ : -CH ₃	R ⁴ : -CN	
(11)	Al	R ¹ : -CH ₃	R ⁴ : -Cl	

[0025]

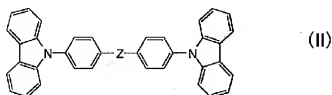
[Table 2]

番号	M	R ¹ ~R ³	R ⁴ ~R ⁶	X
(12)	Al	R ¹ : -CH ₃	—	
(13)	Al	R ¹ : -CH ₃ R ³ : -CH ₃	—	
(14)	Al	R ¹ : -CH ₃	R ⁴ : -CN	
(15)	Al	R ¹ : -CH ₃ R ³ : -CH ₃	R ⁴ : -CN	
(16)	Ga	R ¹ : -CH ₃ R ² : -CH ₃	R ⁴ : -CN	
(17)	Al	R ¹ : -CH ₃	—	
(18)	Al	R ¹ : -CH ₃	R ⁴ : -CN	
(19)	Al	R ¹ : -CH ₃ R ² : -CH ₃	—	
(20)	Ga	R ¹ : -CH ₃ R ³ : -CH ₃	—	

[0026]The thing which is not shown by R¹ - R⁶ in particular and the thing indicated to be "-" express a hydrogen atom among front. These compounds may be used independently, and if needed, it may mix respectively and they may be used. As a compound which has N-phenyl carbazole skeleton contained in the luminous layer in the organic electroluminescence devices of this invention, it is following general formula (II) preferably.

[0027]

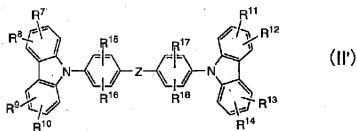
[Chemical formula 11]



[0028](Z shows a divalent connecting group among a formula.) The carbazoyl group and the phenylene group may have arbitrary substituents respectively. The compound expressed is mentioned and it is a following general formula (II') more preferably.

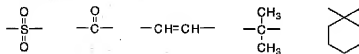
[0029]

[Chemical formula 12]



[0030]the inside of a formula, $R^7 - R^{18}$ -- each -- independent -- a hydrogen atom and a halogen atom. An alkyl group, an aralkyl group, an alkenyl group, a cyano group, an amino group, an acyl group, An alkoxycarbonyl group, a carboxyl group, an alkoxy group, an alkylamino group, An aralkyl amino group, a HAROARUKIRU group, a hydroxyl group, an aryloxy group, The aromatic-hydrocarbon-rings group or aromatic heterocycle group which may have a substituent is expressed, R^7 , R^8 and R^9 , R^{10} and R^{11} , R^{12} and R^{13} , R^{14} and R^{15} , R^{16} and R^{17} , and R^{18} may form a ring by adjoining substituents, respectively. The connecting group which Z shows a divalent connecting group and is more specifically shown in direct coupling, an oxygen atom, a sulfur atom, and the following, [0031]

[Chemical formula 13]



[0032]It is expressed with the aromatic-hydrocarbon-rings group or aromatic heterocycle group which may have a substituent, the general formula (IIa) shown below, or (IIb). [or]

[0033]

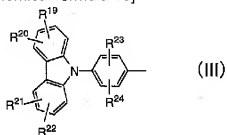
[Chemical formula 14]



[0034](Ar⁶ and Ar⁷ are denoted respectively independently by the divalent aromatic-hydrocarbon-rings group or aromatic heterocycle group which may have a substituent, or general formula (III) of the following among a formula.)

[0035]

[Chemical formula 15]



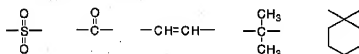
[0036]the inside of a formula, R¹⁹ - R²⁴ -- each -- independent -- a hydrogen atom and a halogen atom. An alkyl group, an aralkyl group, an alkenyl group, a cyano group, an amino group, an acyl group, An alkoxy carbonyl group, a carboxyl group, an alkoxy group, an alkylamino group, An aralkyl amino group, a HAROARUKIRU group, a hydroxyl group, an aryloxy group, The aromatic-hydrocarbon-rings group or aromatic heterocycle group which may have a substituent may be expressed, and R¹⁹, R²⁰ and R²¹, R²² and R²³, and R²⁴ may form a ring by adjoining substituents, respectively. The compound expressed is mentioned.

[0037]In said general formula (II'), as R⁷-R¹⁸, specifically, hydrogen atom; -- halogen atom; -- the alkenyl-group; cyano group; amino group; acyl group; methoxy group of the carbon numbers 2-6, such as aralkyl group; vinyl groups, such as alkyl-group; benzyl of the carbon numbers 1-6, such as a methyl group and an ethyl group,. The alkoxy group of the carbon numbers 1-6, such as an ethoxy group; A methoxycarbonyl group, alkoxy carbonyl group [of the carbon numbers 2-6 of an ethoxycarbonyl group etc.]; -- carboxyl group; -- a phenoxy group. Aryloxy groups, such as a benzyloxy group; Dialkylamino group; dibenzylamino groups, such as a diethylamino group and a diisopropylamino group, diaralkylamino group [, such as a diphenethyl amino group,]; -- alpha-HAROARUKIRU group [, such as a trifluoromethyl group,]; -- hydroxyl group; -- aromatic heterocycle groups which may have aromatic-hydrocarbon-rings group; substituents, such as a phenyl group, a naphthyl group, etc. which may have a substituent, such as a thienyl group and a pyridyl group, are expressed.

[0038][as a substituent which said aromatic-hydrocarbon-rings group and an aromatic heterocycle group can take] Halogen atoms, such as a fluorine atom; The alkenyl-group;

methoxycarbonyl group of the carbon numbers 2-6, such as an alkyl-group; vinyl group of the carbon numbers 1-6, such as a methyl group and an ethyl group, The alkoxycarbonyl group of the carbon numbers 2-6 of an ethoxycarbonyl group etc.; A methoxy group, The alkoxy group of the carbon numbers 1-6, such as an ethoxy group; HAROARUKIRU group; cyano groups, such as acyl group; trifluoromethyl groups, such as dialkylamino group; acetyl groups, such as aryloxy group; dimethylamino group; diethylamino groups, such as a phenoxy group and a benzyloxy group, etc. are mentioned.

[0039]It may join together by adjoining substituents and R^7 , R^8 and R^9 , R^{10} and R^{11} , R^{12} and R^{13} , R^{14} and R^{15} , R^{16} and R^{17} , and R^{18} may form benzene ring, a cyclohexane ring, etc., respectively. The connecting group which Z shows a divalent connecting group and is preferably shown in direct coupling, an oxygen atom, a sulfur atom, and the following, [0040]
[Chemical formula 16]



[0041]It is expressed with either aromatic heterocycle groups which may have a substituent, such as aromatic-hydrocarbon-rings groups, such as benzene ring, or a thiophene ring, or the general formula (IIa) shown below (IIb).

[0042]

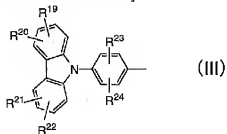
[Chemical formula 17]



[0043] Ar^6 and Ar^7 are denoted respectively independently by aromatic heterocycle groups which may have a substituent, such as aromatic-hydrocarbon-rings groups, such as benzene ring and a naphthalene ring, or a thiophene ring, a furan ring, and a pyridine ring, or general formula (III) of the following among a formula.

[0044]

[Chemical formula 18]



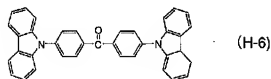
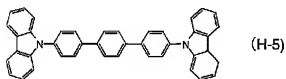
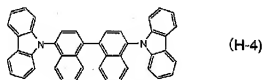
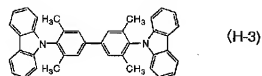
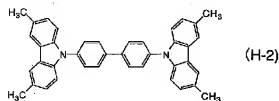
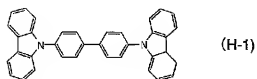
[0045]Respectively R^{19} - R^{24} independently among a formula A hydrogen atom; halogen atom; methyl group, alkyl-group [of the carbon numbers 1-6, such as an ethyl group,]; -- aralkyl group [, such as benzyl,]; -- alkenyl-groups [, such as a vinyl group,]; -- cyano group; -- amino group; -- acyl group; -- a methoxy group. The alkoxy group of the carbon numbers 1-6, such as an ethoxy group; A methoxycarbonyl group, alkoxycarbonyl group [of the carbon numbers 2-6 of an ethoxycarbonyl group etc.]; -- carboxyl group; -- a phenoxy group. Aryloxy groups, such as a benzyloxy group; Dialkylamino group; dibenzylamino groups, such as a diethylamino group and a diisopropylamino group, diaralkylamino group [, such as a diphenethyl amino group,]; -- alpha-HAROARUKIRU group [, such as a trifluoromethyl group,]; -- hydroxyl group; -- aromatic heterocycle groups which may have aromatic-hydrocarbon-rings group; substituents, such as a phenyl group, a naphthyl group, etc. which may have a substituent, such as a thienyl group and a pyridyl group, are expressed.

[0046][as a substituent which said aromatic-hydrocarbon-rings group and an aromatic heterocycle group can take] Halogen atoms, such as a fluorine atom; The alkenyl-group; methoxycarbonyl group of the carbon numbers 2-6, such as an alkyl-group; vinyl group of the carbon numbers 1-6, such as a methyl group and an ethyl group, The alkoxycarbonyl group of the carbon numbers 1-6 of an ethoxycarbonyl group etc.; A methoxy group, The alkoxy group of the carbon numbers 1-6, such as an ethoxy group; HAROARUKIRU group; cyano groups, such as acyl group; trifluoromethyl groups, such as dialkylamino group; acetyl groups, such as aryloxy group; dimethylamino groups, such as a phenoxy group and a benzyloxy group, and a diethylamino group, etc. are mentioned.

[0047]It may join together by adjoining substituents and R^{19} , R^{20} and R^{21} , R^{22} and R^{23} , and R^{24} may form benzene ring and a cyclohexane ring ring, respectively. Although the desirable example of a compound denoted by said general formula (II') is shown below, it does not limit to these.

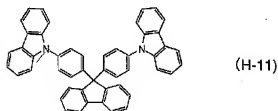
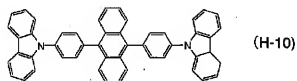
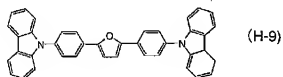
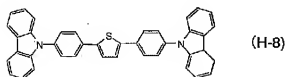
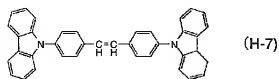
[0048]

[Chemical formula 19]



[0049]

[Chemical formula 20]

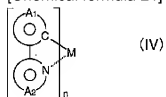


[0050] These compounds may be used independently, and if needed, it may mix respectively and they may be used. Next, the organometallic complex containing at least one metal which is contained in the luminous layer in the organic electroluminescence devices of this invention, and which is chosen from periodic table 7 thru/or 11 groups is explained. As metal which the organometallic complex of this phosphorescence contains, ruthenium, rhodium, palladium, silver, rhenium, osmium, iridium, platinum, and gold are mentioned preferably.

[0051] These organometallic complexes are denoted, for example by following general formula (IV).

[0052]

[Chemical formula 21]



[0053]M expresses metal among a formula and n expresses the valence of this metal. Ring A₁ expresses the aromatic-hydrocarbon-rings group or aromatic heterocycle group which may have a substituent, and expresses a phenyl group, a biphenyl group, a naphthyl group, an anthryl group, a thienyl group, a pyridyl group, a quinolyl group, or an isoquinolyl group preferably. As a substituent which these may have, halogen atom; methyl groups, such as a fluorine atom, alkyl-group [of the carbon numbers 1-6, such as an ethyl group,]; -- alkenyl-group [of the carbon numbers 2-6, such as a vinyl group,]; -- a methoxycarbonyl group. The alkoxycarbonyl group of the carbon numbers 2-6 of an ethoxycarbonyl group etc.; A methoxy group, The alkoxy group of the carbon numbers 1-6, such as an ethoxy group; HAROARUKIRU group; cyano groups, such as acyl group; trifluoromethyl groups, such as dialkylamino group; acetyl groups, such as aryloxy group; dimethylamino groups, such as a phenoxy group and a benzyloxy group, and a diethylamino group, etc. are mentioned.

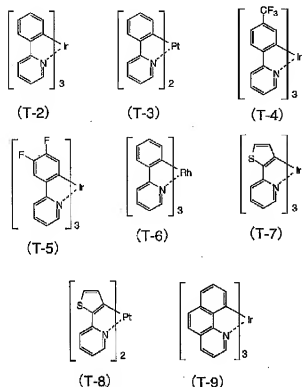
[0054]Ring A₂ expresses the nitrogen-containing aromatic heterocycle group which may have a substituent, and preferably, A pyridyl group, a pyrimidyl group, a pyrazine group, a triazine group, a benzothiazole group, a benzooxazol group, a benzimidazole group, a quinolyl group, an isoquinolyl group, a quinoxaline group, or a phenanthridine group is expressed. As a substituent which these may have, halogen atom; methyl groups, such as a fluorine atom, alkyl-group [of the carbon numbers 1-6, such as an ethyl group,]; -- alkenyl-group [of the carbon numbers 2-6, such as a vinyl group,]; -- a methoxycarbonyl group. The alkoxycarbonyl group of the carbon numbers 2-6 of an ethoxycarbonyl group etc.; A methoxy group, The alkoxy group of the carbon numbers 2-6, such as an ethoxy group; HAROARUKIRU group; cyano groups, such as acyl group; trifluoromethyl groups, such as dialkylamino group; acetyl groups, such as aryloxy group; dimethylamino groups, such as a phenoxy group and a benzyloxy group, and a diethylamino group, etc. are mentioned.

[0055]When the substituent which ring A₁ has, and the substituent which ring A₂ has join together, one condensed ring may be formed and a 7,8-benzoquinoline group etc. are mentioned as such an example. As a substituent of ring A₁ and ring A₂, an alkyl group, an alkoxy group, an aromatic-hydrocarbon-rings group, or a cyano group is mentioned more preferably. Ruthenium, rhodium, palladium, silver, rhenium, osmium, iridium, platinum, or gold is mentioned preferably as M in formula (IV).

[0056]Although the example of the organometallic complex shown by said general formula (IV) is shown below, it is not necessarily limited to the following compound.

[0057]

[Chemical formula 22]



[0058] Hereafter, the organic electroluminescence devices of this invention are explained, referring to Drawings. drawing 1 is a sectional view showing typically the constructional example of the general organic electroluminescence devices used for this invention -- 1 -- a positive hole transportation layer and 5 express a luminous layer, 6 expresses a hole blocking layer, and, as for a substrate and 2, 8 expresses a cathode respectively, as for an anode and 4. The substrate 1 serves as a base material of organic electroluminescence devices, and the board of quartz or glass, a metal plate, a metallic foil and plastic film, a sheet, etc. are used. The board of transparent synthetic resins, such as a glass plate, polyester, polymethacrylate, polycarbonate, polysulfone, is especially preferred. To use a synthetic resin substrate, it is necessary to care about gas barrier nature. Since organic electroluminescence devices may deteriorate by the open air which passed the substrate when the gas barrier property of a substrate is too small, it is not desirable. For this reason, the method of providing precise silicon oxide etc. at least in one side of a synthetic resin substrate, and securing gas barrier nature is also one of the desirable methods.

[0059] Although the anode 2 is formed on the substrate 1, the anode 2 plays the role of the hole injection to a positive hole transportation layer. This anode usually An aluminium, gold, silver, nickel, palladium, It is constituted by conductive polymers, such as halogenated metals, such as metal oxides, such as an oxide of metal, such as platinum, indium, and/or tin, and copper iodide, carbon black or poly (3-methylthiophene), polypyrrole, and poly aniline, etc. Formation of the anode 2 is usually performed by a sputtering process, vacuum deposition method, etc. in

many cases. In the case of particles, such as metal particles, such as silver, and copper iodide, carbon black, a conductive metal oxide particle, conductive polymer impalpable powder, etc., the anode 2 can also be formed by distributing in a suitable binder resin solution and applying on the substrate 1. A thin film can be directly formed on the substrate 1 by electrolytic polymerization, or on the substrate 1, in the case of a conductive polymer, a conductive polymer can be applied, and it can also form the anode 2 (Appl.Phys.Lett., 60 volumes, 2711 pages, 1992). The anode 2 can also be laminated and formed by a different substance. The thickness of the anode 2 changes with transparency to need. When transparency is needed, it is desirable to usually make permeability of visible light into not less than 80% preferably not less than 60%, and 5-1000 nm of thickness is usually about 10-500 nm preferably in this case. When it may be opaque, the anode 2 may be the same as that of the substrate 1. It is also possible to laminate a different electrical conducting material on the above-mentioned anode 2.

[0060]The positive hole transportation layer 4 is formed on the anode 2. As conditions required of the material of a positive hole transportation layer, the hole injection efficiency from an anode is high, and it is required to be the material which can convey the poured-in positive hole efficiently. For that purpose, ionization potential is small, from the light of visible light, transparency is high, hole mobility is large, it excels in stability further, and, moreover, it is required that it should be hard to generate the impurity used as a trap at the time of manufacture and use. In the case of the element of the composition of drawing 1, quenching luminescence from a luminous layer, in order to touch the luminous layer 5, or forming exciplex between luminous layers and not reducing efficiency is called for. When the application for an in-vehicle display is considered in addition to the above-mentioned general demand, a heat-resisting property is further required of an element. Therefore, the material which has a value of not less than 85 °C as Tg is desirable.

[0061]The aromatic diamine which two or more fused aromatic rings substituted by the nitrogen atom as such a hole transporting material including two or more tertiary amine represented with 4,4'-bis[N-(1-naphthyl)-N-phenylamino] biphenyl, for example (JP,H5-234681,A), 4,4',4'' -- the aromatic amine compound (J. Lumin. -- 72 to 74 volumes) which has starburst structures, such as - tris (1-naphthyl phenylamino) triphenylamine the aromatic amine compound (Chem.Comm. -- 2175 pages) which will comprise the tetramer of triphenylamine in 985 pages and 1997 Spiro-compounds (Synth. Metals, 91 volumes, 209 pages, 1997), such as 2,2',7,7'-tetrakis (diphenylamino)-9,9'-spirobifluorene, etc. will be mentioned in 1996. These compounds may be used independently, and if needed, it may mix respectively and they may be used.

[0062]In addition to the above-mentioned compound, as a material of the positive hole transportation layer 4, polyvinyl carbazole, Polymeric materials, such as polyarylene ether

SARUHON (Polym. Adv. Tech., seven volumes, 33 pages, 1996) containing polyvinyl triphenylamine (the No. publication-number 7- 53953 gazette) and tetraphenylbenzidine, are mentioned. In the case of the applying method, additives which do not become a trap of a positive hole according to one sort or two sorts or more, and necessity about a hole transporting material, such as binder resin and a spreading nature improving agent, are added, it dissolves, a coating solution is prepared, and it applies on the anode 2 by methods, such as a spin coat method, and it dries and the positive hole transportation layer 3b is formed. Polycarbonate, polyarylate, polyester, etc. are mentioned as binder resin. Since it will reduce hole mobility if binder resin has many amounts of addition, few directions are desirable and its 50 or less weight % is usually preferred.

[0063]In the case of a vacuum deposition method, a crucible is heated, after paying a hole transporting material to the crucible installed in the vacuum vessel and exhausting the inside of a vacuum vessel even to a 10^{-4} Pa grade with a suitable vacuum pump, The positive hole transportation layer 4 is made to form on the substrate 1 which the hole transporting material was evaporated, and faced the crucible and was placed and with which the anode was formed. the thickness of the positive hole transportation layer 4 -- usually -- 5-300 nm -- desirable -- it is 10-100 nm. Thus, in order to form a thin film uniformly, generally a vacuum deposition method is used well.

[0064]The luminous layer 5 is formed on the positive hole transportation layer 4. In inter-electrode [which was able to give the electric field including the organometallic complex containing the compound which has N-phenyl carbazole skeleton which the luminous layer 5 mentioned above and the metal chosen from periodic table 7 thru/or 11 groups who mentioned above], It is excited by the recombination of the positive hole which is poured in from an anode and moves a positive hole transportation layer, and the electron which is poured in from a cathode and moves the hole blocking layer 6, and strong luminescence is shown.

[0065]The luminous layer in the organic electroluminescence devices of this invention contains said organometallic complex for the compound which has said N-phenyl carbazole skeleton, and the compound which has said N-phenyl carbazole skeleton as a principal component more preferably although said organometallic complex is contained as an accessory constituent again. A "principal component" means what occupies 50 weight % or more in the material which forms this layer, and an "accessory constituent" means here what occupies less than 50 weight % in the material which forms this layer. The luminous layer 5 is a range which does not spoil the performance of this invention, and other host materials (the same work as the compound which has N-phenyl carbazole skeleton is performed), fluorescence pigments, etc. may contain other components.

[0066]As for the quantity which the organometallic complex denoted by said general formula (IV) contains in a luminous layer, it is preferred that it is in 0.1 to 30weight % of the range. At

0.1 or less weight %, if it cannot contribute to the improvement in luminous efficiency of an element but 30 weight % is exceeded, concentration quenching of organometallic complexes forming a dimer will occur, and it will result in decline in luminous efficiency. In the element using the conventional fluorescence (singlet), there is a tendency for more [a little] ones to be more preferred than the quantity of the fluorescence pigment (dopant) contained in a luminous layer. An organometallic complex may be partially contained to a thickness direction in a luminous layer, or may be distributed unevenly.

[0067]the thickness of the luminous layer 5 -- usually -- 10 - 200 nm -- it is 20 - 100 nm preferably. Thin film forming is carried out by the same method as the positive hole transportation layer 4. In this invention, the layer containing the compound denoted by said general formula (I) as a hole blocking layer is arranged in contact with the interface by the side of the cathode 8 of the luminous layer 5. The hole blocking layer 6 is formed from the compound which can convey efficiently the role which prevents arriving at a cathode the positive hole where it moves from a positive hole transportation layer, and the electron poured in from the cathode in the direction of a luminous layer. It is needed that electron mobility is high and hole mobility is low as physical properties for which the material which constitutes a hole blocking layer is asked. The hole blocking layer 6 shuts up a positive hole and an electron in a luminous layer, and has a function which raises luminous efficiency.

[0068]the hole blocking layer material which fulfills such conditions -- carrying out -- the mixed ligand complex denoted by said general formula (I) is mentioned. the thickness of the hole blocking layer 6 -- usually -- 0.3 to 100 nm -- desirable -- -- it is 0.5-50 nm. Although a hole blocking layer can also be formed by the same method as a positive hole transportation layer, a vacuum deposition method is usually used.

[0069]The cathode 8 plays the role which pours an electron into the luminous layer 5 via the hole blocking layer 6. Although the material used as the cathode 8 can use the material used for said anode 2, In order to perform electron injection efficiently, the low metal of a work function is preferred and suitable metal or those alloys, such as tin, magnesium, indium, calcium, an aluminium, and silver, are used. As an example, low work function alloy electrodes, such as a magnesium silver alloy, a magnesium indium alloy, and an aluminium-lithium alloy, are mentioned. To the interface of a cathode, a luminous layer, or an electron transport layer, LiF, MgF_2 , [also intercalating ultra-thin insulating layers (0.1-5 nm), such as Li_2O] It is the effective method of raising the efficiency of an element (Appl. Phys. Lett., 70 volumes, 152 pages, 1997; No. publication-number 10- 74586 gazette;IEETrans. Electron. Devices, 44 volumes, 1245 pages, 1997). The thickness of the cathode 8 is usually the same as that of the anode 2. It increases the stability of an element that a work function laminates a stable metal layer to the air further highly on this in order to protect the cathode which comprises a low work function metal. For this purpose, metal, such as an aluminium, silver,

copper, nickel, chromium, gold, and platinum, is used.

[0070]It is possible to form the electron transport layer 7 between the hole blocking layer 6 and the cathode 8 for the purpose of raising the luminous efficiency of an element further (refer to drawing 2). The electron transport layer 7 is formed from the compound which can convey efficiently the electron poured in from the cathode in inter-electrode [which was able to give the electric field] in the direction of the hole blocking layer 6. It is required for the electron injection efficiency from the cathode 8 to be a compound which can convey efficiently the electron which has high electron mobility and was poured in highly as an electron-transport-property compound used for the electron transport layer 7.

[0071]As a material which fulfills such conditions, metal complexes, such as an aluminium complex of 8-hydroxyquinoline (JP,S59-194393,A), The metal complex of 10-hydroxy benzo[h]quinoline, an oxadiazole derivative, A distyrylbiphenyl derivative, a silole derivative, 3-, or a 5-hydroxy flavone metal complex, A benzoxazole metal complex, a benzothiazole metal complex, tris benzimidazolyl benzene (U.S. Pat. No. 5,645,948), A quinoxaline compound (JP,H6-207169,A), a phenanthroline derivative (JP,H5-331459,A), 2-t-butyl-9,10-N,N'-dicyano anthraquinone diimine, n type hydrogenation amorphous carbonization silicon, n type zinc sulfide, n type zinc selenide, etc. are mentioned. 5-200 nm of thickness of the electron transport layer 6 is usually 10 - 100 nm preferably.

[0072]The electron transport layer 7 is formed by laminating on the hole blocking layer 6 by the applying method or a vacuum deposition method like the positive hole transportation layer 4. Usually, a vacuum deposition method is used. Intercalating the anode buffer layer 3 between the positive hole transportation layer 4 and the anode 2 is also performed the raising the efficiency of hole injection further and making the adhesion force to the anode of the whole organic layer improve purpose (refer to drawing 3). By intercalating the anode buffer layer 3, it is effective in a voltage rise when the continuation drive of the element is carried out by constant current being controlled at the same time the drive voltage of an early element falls. A thin film with it can be formed, stability, i.e., a melting point, and glass transition temperature are thermally high, and more than 100 °C is required as more than 300 °C and a glass transition temperature as a melting point. [good contact to an anode and] [uniform as conditions required of the material used for an anode buffer layer] It is mentioned that ionization potential is low and the hole injection from an anode is easy and that hole mobility is large.

[0073]Until now for this purpose TAROSHIANIN compounds, such as copper phthalocyanine (JP,S63-295695,A), Poly aniline (Appl. Phys. Lett., 64 volumes, 1245 pages, 1994), polythiophene (Optical Materials -- 125 pages nine volumes) the organic compounds in 1998 etc., and a sputtering carbon film (Synth. Met. -- 91 volumes) Metal oxides (J. Phys. D, 29 volumes, 2750 pages, 1996), such as 73 pages, 1997, a vanadium oxide, a ruthenium oxidation thing, a molybdenum oxide, are reported.

[0074]Although thin film forming is possible also for the case of an anode buffer layer like a positive hole transportation layer, when it is an inorganic substance, a sputtering method, electron beam evaporation method, and plasma CVD method are used further. the thickness of the anode buffer layer 3 formed as mentioned above -- usually -- 3-100 nm -- desirable -- -- it is 5-50 nm.

[0075]It is also possible to laminate on a structure contrary to drawing 1, i.e., a substrate, in order of the cathode 8, the hole blocking layer 6, the luminous layer 5, the positive hole transportation layer 4, and the anode 2, and at least one side is able to provide the organic electroluminescence devices of this invention between two substrates with high transparency, as mentioned already. It is also possible similarly to laminate in a structure contrary to said class composition shown in drawing 2 and drawing 3.

[0076]Also in any of the structure where the single element, the element which consists of structure where it has been arranged at array form, the anode, and the cathode have been arranged at X-Y matrix form, organic electroluminescence devices can apply this invention. According to the organic electroluminescence devices of this invention, the compound which has a specific skeleton to a luminous layer Since the high compound with stable thin film shape of positive hole stopping power power is used for the hole blocking layer, The element with which luminous efficiency has been highly improved greatly also in driving stability rather than the element using luminescence from the conventional singlet state is obtained, and full color or the performance outstanding in the application to the panel of multicolor can be demonstrated.

[0077]

[Working example]Next, although an embodiment explains this invention still more concretely, this invention is not limited to the description of the following embodiments, unless the gist is exceeded.

The organic electroluminescence devices which have the structure shown in embodiment 1 drawing 3 were produced by the following methods.

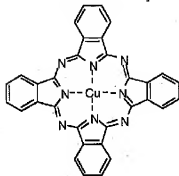
[0078]It is an indium-tin-oxide (ITO) transparent conducting film on a glass substrate. What was deposited 150 nm (Geomatec make; electron beam membrane formation article; 15ohms of sheet resistance) was patterned after the stripe of 2-mm width using the usual photolithography technique and hydrochloric acid etching, and the anode was formed. The ITO board which carried out pattern formation was dried by the nitrogen blow after washing in order of ultrasonic cleaning by acetone, the flush by pure water, and ultrasonic cleaning by isopropyl alcohol, finally the ultraviolet radiation ozone wash was performed, and it installed in the vacuum evaporation system. It exhausted using the oil diffusion pump provided with the liquid nitrogen trap after the oil sealed rotary pump performed rough exhaust air of the above-mentioned device until the degree of vacuum in a device became below 2×10^{-6} Torr (about 2,

7×10^{-4} Pa).

[0079] It vapor-deposited by heating the copper phthalocyanine (a crystal form is beta type) shown in the following put into the molybdenum combustion boat arranged in the above-mentioned device. It vapor-deposited in degree-of-vacuum 2×10^{-6} Torr (about 2.7×10^{-4} Pa), and vacuum evaporation time 1 minute, and the anode buffer layer 3 of 10 nm of thickness was obtained.

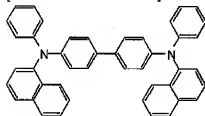
[0080]

[Chemical formula 23]



[0081] Next, 4,4'-bis[N-(1-naphthyl)-N-phenylamino] biphenyl which was put into the ceramic crucible arranged in said device and which is shown below [0082]

[Chemical formula 24]



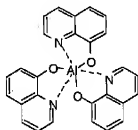
[0083] It vapor-deposited by heating with the tantalum wire heater around a crucible. The temperature of the jar which gets at this time was controlled in 280-270 **. The positive hole transportation layer 4 of 60 nm of thickness was obtained in degree-of-vacuum 1.5×10^{-6} Torr at the time of vacuum evaporation (about 2.0×10^{-4} Pa), and vacuum evaporation time 3 minutes. Then, the iridium complex in which the compound (H-1) which has N-phenyl carbazole skeleton was shown by (T-2) as a phosphorescence organometallic complex as luminous layer 5 principal component was installed in the separate ceramic crucible, and 2 yuan formed membranes with simultaneous vacuum deposition. It is considered as the range of 210-220 **, and the jar temperature, as for, a compound (H-1) gets is an evaporation rate. It controls [second] in 0.2nm /, The iridium complex (T-2) was controlled to a 290-295 ** temperature span, and laminated the luminous layer 5 which the iridium complex (T-2) contained 5weight %

by 30 nm of thickness on the positive hole transportation layer 4. The degree of vacuum at the time of vacuum evaporation was 1.1×10^{-6} Torr (about 1.5×10^{-4} Pa).

[0084] It is crucible temperature about the compound (12) shown in Table 2 as the hole blocking layer 6. It was considered as 220 °C and laminated by 10-nm thickness with the evaporation rate of 0.1 nm/second. The degree of vacuum at the time of vacuum evaporation was 1.0×10^{-6} Torr (about 1.3×10^{-4} Pa). On the hole blocking layer 6, 8-hydroxyquinoline complex of the aluminium shown in the following constitutional formulas as the electron transport layer 7 and aluminum(C_9H_6NO)₃ were vapor-deposited similarly.

[0085]

[Chemical formula 25]



[0086] Crucible temperature of 8-hydroxyquinoline complex of the aluminium at this time It controlled in the range of 280 to 300 °C, and the degree of vacuum at the time of vacuum evaporation was set to 1.0×10^{-6} Torr (about 1.3×10^{-4} Pa), and thickness was 35 nm in evaporation rate in a second in 0.2 nm/. When carrying out the vacuum deposition of the above-mentioned anode buffer layer, positive hole transportation layer, luminous layer, hole blocking layer, and electron transport layer, substrate temperature was held to the room temperature.

[0087] The element which performed vacuum evaporation to the electron transport layer 7 is once taken out from the inside of said vacuum evaporation system in the air here, As a mask for cathode vacuum evaporation, [the stripe shape shadow mask of 2 mm width] It was made to stick to an element so that it may intersect perpendicularly with the ITO stripe of the anode 2, and it exhausted until it installed in another vacuum evaporation system and the degree of vacuum in a device became below 2×10^{-6} Torr (about 2.7×10^{-4} Pa) like the organic layer. Magnesium fluoride (MgF_2) was first formed on the electron transport layer 7 by the thickness

of 1.5 nm by evaporation rate [of 0.1 nm/second], and degree-of-vacuum 7.0×10^{-6} Torr (about 9.3×10^{-4} Pa), using a molybdenum combustion boat as the cathode 8. Next, the aluminium was similarly heated by the molybdenum combustion boat, and the aluminum layer of 40 nm of thickness was formed by the evaporation rate of 0.5 nm/second, and degree-of-vacuum 1×10^{-6}

⁵Torr (about 1.3×10^{-3} Pa). On it, in order to improve the conductivity of a cathode, silver was similarly heated by the molybdenum combustion boat, the silver layer of 40 nm of thickness was formed by the evaporation rate of 0.3 nm/second, and degree-of-vacuum 1×10^{-5} Torr (about 1.3×10^{-3} Pa), and the cathode 8 was completed. The substrate temperature at the time of vacuum evaporation of the above three-layer type cathode 8 was held to the room temperature.

[0088]The organic electroluminescence devices which have an emission area portion of the size of 2mmx2mm as mentioned above were obtained. The emitting properties of this element are shown in table-3. In table-3, the value in 100 cds /, and m^2 , and luminance/electric current show inclination of luminance-current density characteristics, and, as for luminescent brightness, voltage shows respectively the value in 100 cds /, and m^2 , as for the value in the current density of $250 \text{ mA} / \text{cm}^2$, and luminous efficiency. Maximum wavelength of the emission spectrum of an element It is 512 nm and was identified the thing from an iridium complex (T-2).

[0089]

[Table 3]

表-3

	発光輝度 [cd/m ²] @250mA/cm ²	発光効率 [lm/W] @100 cd/m ²	輝度/電流 [cd/A]	電圧 [V] @100 cd/m ²	発光極大 [nm]
実施例 1	31170	12.3	24.6	6.3	512
実施例 2	26970	10.6	21.3	5.4	512
実施例 3	6500	2.1	4.7	7.0	585
比較例 1	29890	19.5	31.8	5.2	512
比較例 2	9030	1.6	3.1	6.2	518

[0090]The result evaluated by brightness lowering when the heat resistance test of this element was driven with high current density called 250 mA/cm^2 is shown in the graph of drawing 4.

The compound (13) shown in Table 2 was used as embodiment 2 hole blocking layer, and also the element was produced like Embodiment 1. Emitting properties are shown in table-3. The result of the driving stability examination in high current density done like Embodiment 1 is shown in the graph of drawing 4.

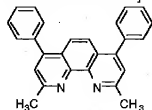
[0091]The compound (T-8) was used as a phosphorescence organometallic complex which embodiment 3 luminous layer is made to contain, and also the element was produced like

Embodiment 1. Emitting properties are shown in table-3. Luminescence of orange peculiar to a platinum complex (T-8) was observed.

As comparative example 1 hole blocking layer, it is the following phenanthroline derivative.

[0092]

[Chemical formula 26]



[0093]***** produced the element like Embodiment 1. The emitting properties of this element are shown in the graph of table-3 and drawing 4. It became clear that the driving stability in high current density is low.

Comparative example 2 hole blocking layer was not used, and also the element was produced like Embodiment 1. The emitting properties of this element are shown in table-3. The fall especially with big luminous efficiency was seen.

[0094]

[Effect of the Invention]According to the cathode of the organic electroluminescence devices of this invention, it becomes in undervoltage, it is high-intensity and efficient, and possible to make light emit, and the element which is still more stable also in the drive of high current density, and has little deterioration at the time of preservation can be obtained. The organic electroluminescence devices by this invention Therefore, a flat panel display (for example, the object for OA computers and a flat TV), The application to the light source (for example, the light source of a copying machine, the back light light source of a liquid crystal display or instruments), display board, and beacon light which employed the feature as an in-vehicle indicating element, and a cellular-phone display and a surface light object efficiently can be considered, and the technical value is large.

[Translation done.]